THE SEARCH FOR EXTRATERRESTRIAL LIFE

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The Challenge

"Le silence eternel des espaces infinis m'effraie," wrote Pascal in his Pensees. To our ancestors the vastness of the earth was an awesome fact which influenced their thoughts and lives. But, today, in the brief span of a few hours we can fly over continents or cross the oceans. From a world that has become too small, we are moving out into one that will be forever too large, whose frontiers will recede from us almost before we reach for them. We are now able to determine the nature of matter in the depths of the stars. A century ago such an achievement would have been deemed impossible. Today, rockets can carry our spaceships to the neighbouring planets. A generation ago such a feat belonged only to the realm of fantasy. Yet, in spite of all this knowledge, we are awed by the mystery of the universe around us. The question looms larger than ever: Are we alone in the universe? If we sample the alien dust of another world, what hidden secrets may we not discover? If we track the radio waves from a distant galaxy, what may we not hear if we listen closely? If we probe deep into the chemistry of life's origin, what may we not discern about the possibility of its existence elsewhere in the universe?

Nearly five centuries ago Columbus stood on the shores of the Atlantic and gazed at the horizon extending before him. When most people thought his quest foolish, the spirit of adventure and the urge to explore impelled him across the waves. Like Columbus, the modern space explorer faces a new horizon that stretches almost to infinity. He is urged on as Ulysses was: "Oh, brothers, through a hundred thousand perils have ye driven to the West. Now in the brief and tiny span that still remains to you of waking life, refuse not to explore whatever lies beyond the sun." The spirit of this search is the quintessence of the new science of exobiology.

In an authoritative document the National Academy of Sciences has set down the search for extraterrestrial life as the prime goal of space biology: "It is not since Darwin and, before him, Copernicus, that science has had the opportunity for so great an impact on man's understanding of man. The scientific question at stake in exobiology is the most exciting, the most challenging, and profound issue, not only of this century, but of the entire naturalistic movement that has characterized the history of western thought for over 300 years. If there is life on Mars and if we can demonstrate its independent origin, then we shall have an enlightening answer to the question of the improbability and uniqueness in the origin of life. Arising twice in a single planetary system, it must surely occur abundantly elsewhere in the staggering number of comparable planetary systems."

Life in the Universe

Almost 2,000 years ago Lucretius wrote of beings that dwell in other worlds.

"And if the selfsame laws of nature hold
Which have the power to cast the seeds of things
Together in their several places, e'en
As here they are together thrown, perforce
Thou must confess that other worlds exist
In other realms of space, and divers tribes
Of human kind and breeds of savage beasts."

Modern astronomy by its exhaustive study of galactic, stellar, and planetary evolution has come to the inescapable conclusion that life in the universe must be of common occurrence. Sampling of galaxy population to the limit attainable by present telescopes, shows that there are more than 10^{20} stars in the universe. Like our own sun, each one of these stars can provide the energy for plant and animal life. Two factors become abundantly clear: that there is nothing unique about our sun which is the mainstay of life on this planet, and that there are more than 10^{20} opportunities for the existence of life. If we adopt a process of restriction and suppose: that because of doubling, clustering, secondary collisions, etc., only one star in a thousand has a planetary system; that only one out of a thousand of those stars with systems of planets has one or more planets at the right distance from the star to provide the water and warmth that protoplasm requires; that of these stars only one out of a thousand has a planet large enough to hold an atmosphere; that the suitable chemical composition for life to arise occurs only once in a thousand times; only one star in 10^{12} meets the necessary rigid requirements. Even so, by Harlow Shapley's conservative estimate, there are 10^{8} planetary systems suitable for life.

The astronomer, Su-Shu Huang, has been less rigorous in his requirements for the existence of life in the universe. In considering the time scales of biological and stellar evolution, the habitable zones of a star, dynamic and other considerations, he has come to the astonishing conclusion that at least 5 per cent of the stars in the universe must support life. Huang thus reckons that there must be at least 10^{18} sites for the existence of life.

Harrison Brown has recently used the illuminacy function to estimate the number of invisible planet-like objects in the neighbourhood of the sun. Taking into account the likely chemical composition of planets in relation to the composition of the main sequence stars, he has suggested that there may be about 60 objects more massive than Mars in the neighbourhood of visible stars. According to him, stars, together with cold objects, may have been formed in clusters, random in size. On this basis, virtually every star should have a planetary system associated with it. The conclusion is inevitable, therefore, that the conditions feasible for life processes may be far more abundant than has been generally thought to be possible. On the basis of his calculations, there must be at least a hundred billion planetary systems in our own galaxy.

This conclusion which astronomers have reached by the rigorous analysis of scientific data was already prophetically foretold by Giordano Bruno in the sixteenth century - "Sky, universe, all-embracing ether, and immeasurable space alive with movement--all these are of one nature. In space there are countless constellations, suns, and planets; we see only the suns because they give light; the planets remain invisible, for they are small and dark. There are also numberless earths circling around their suns, no worse and no less inhabited than this globe of ours. For no reasonable mind can assume that heavenly bodies which may be far more magnificent than ours would not bear upon them creatures similar or even superior to those upon our human Earth."

The Search

In our search for the existence of extraterrestrial life, three possible approaches present themselves to us. First, the landing of instruments or man somewhere in the universe. With our present knowledge, this approach would undoubtedly be restricted to our own planetary system. A second approach is via radio contact with civilizations in outer space. This presupposes the existence of intelligent beings in space with a technology as advanced or even greater than our own. Thirdly, we have the experimental approach to the problem. In this approach, life is considered an inevitable consequence of the evolution of matter. Since the laws of chemistry and physics are universal laws, the retracing, in the laboratory, of the path by which life appeared on earth would give strong support to our belief in its existence elsewhere in the universe.

Life on Mars

Our effort to land an instrument or eventually a scientist astronaut on a neighbouring planet is primarily directed to the planet Mars. The possibility of life on Mars has often been raised. The canal-like structures on Mars and the seasonal wave of darkening across the planet have led many to believe that there must be some form of life on Mars. Some have suggested the existence of highly intelligent beings who, by incredible feats of engineering, have saved for themselves the depleting water supply on the planet, by building mammoth canals crisscrossing the planet. All these speculations have fired the imagination of the planetary scientist and have made him determined to find out the answer to the question, "Is there life on Mars?"

When we leave speculation aside and consider the actual conditions that exist on Mars today, the existence of advanced forms of life must be considered very unlikely; however, the physical conditions are such that low forms of life, such as microorganisms, could survive on the planet. The atmosphere of Mars is made up of carbon dioxide, a trace of water, and possibly nitrogen. Oxygen has not been detected and if it exists at all, must be in very low concentration. There must be a high ultraviolet flux which reaches the surface of Mars, since the Martian atmosphere does not appear to have a built-in protection from ultraviolet light, as our own earth. With this high incidence of ultraviolet radiation, Martian organisms would have to protect themselves by burrowing into the surface; or they may have evolved a mechanism compatible with the existence of a high ultraviolet flux.

Polarization and infra-red data have shown that the polar caps of Mars are ice caps. They wax and wane with the seasons. They are probably extremely thin and perhaps not more than a few centimeters in thickness. In the summer, the pole cap recedes at about 35 kilometers per day. As one pole cap recedes, the other appears to form under a cloud. Water thus appears to be transported from pole to pole. A dark band has been observed to follow the receding pole cap. The wave of darkening proceeds from pole to equator at the rate of about 35 kilometers per day during the spring and summer. It is this dark band which has led many to speculate on the existence of vegetation. It seems attractive to interpret this wave of darkening as a gradual growth of vegetation across the planet.

The temperature extremes on Mars may not be incompatible with life. The highest temperature observed during the day near the equator is about 30 degrees centigrade. The night temperatures go well below zero to about -70 degrees. The atmospheric pressure on Mars is disputed. The estimates vary from about 100 millibars to 10 millibars. While this low pressure may not in itself be a factor which affects the survival of microorganisms, it will have an effect on the availability of water. The amount of water present on Mars is about 1/1,000 of that found in the earth's atmosphere. This again does not preclude the existence of micro environments in which above average accumulations of water may occur.

This very sketchy survey of the physical parameters of Mars indicates for us that, although the conditions are rigorous as compared to the earth, they are well within the range in which microorganisms can survive. Indeed, laboratory experiments in which these conditions have been simulated have shown that some earth microorganisms can survive and even multiply under such conditions, if water is available. Furthermore, if we consider planetary evolution, on account of the smallness of the planet Mars, the processes of chemical evolution may have proceeded very rapidly. Higher forms of life may have evolved and disappeared. Visitors to Mars may be greeted by relics or fossils of a once thriving biosphere.

The experimental approach to life detection on Mars could proceed in three stages. Firstly, a fly-by could give us more definite information about the physical parameters of Mars. The opacity of our own atmosphere prevents us from making highly reliable astronomical observations. The second step would be the landing of an instrument on Mars which would possibly detect the presence of microorganisms. If all this succeeds, the necessity for a man landing on Mars will be even greater, for we shall never be completely satisfied with results from mere instrumental life detectors.

Let us now consider a few of the experiments that have been designed for detection of life on Mars and for possible future landing on Mars. A celebrated device is the multivator which is being prepared under the direction of Joshua Lederberg. It is a device about a pound in weight, less than a foot long, 2-1/2 inches in diameter, designed to demonstrate the presence or absence of microscopic life forms in a planet's soil. Initial experiments are planned to detect enzymes of types found in earth bacteria. One such enzyme is called phosphatase. Soil samples blown into the multivator will then be scanned for the presence of these enzymes. A small radio will transmit that information down to earth at about the same speed at which the multivator can generate the information.

Yet another instrument being prepared for life detection on Mars is "Gulliver" or the radio-isotope biochemical probe. A broth or medium is prepared in which almost any form of bacteria will grow. Several of the ingredients are labelled with radioactive isotopes. Particles of dust from the planetary surface will be introduced into the broth. If the dust particles contain living organisms, these organisms will grow in the broth and produce a radioactive gas. The gas will then activate a Geiger counter. The clicking of the Geiger counter is connected with a telemetering device which will transmit the information back to earth.

The Wolf trap is a contrivance named after Wolf Vishniac of the University of Rochester. The Wolf trap consists of a hollow tube from which air has been removed to create a vacuum. The internal vacuum will thus suck dust into the tube. Inside the cylinder cultural media will be exposed in which bacteria can grow. If successful growth results, the turbidity of the medium will change and so will the H^+ concentration. When either of these changes occur, the detecting devices will transmit the information back to earth.

Numerous other accoutrements have been prepared for possible eventual landing on Mars, to tell us whether there are molecules of biological significance. Among these may be mentioned the gas chromatograph, the mass spectrometer, the J-band detector, and the ultraviolet spectrophotometer. Prodigious feats of engineering will be required to miniaturize these apparatus for eventual possible landing.

Very recently, however, on account of the availability of high powered boosters, it has even been possible to think in terms of much more comprehensive methods for life detection. In the devices so far discussed, the experiments are single experiments designed to test one or other attributes of life as we know it, but now we have with us the possibility of even landing an automated biochemical laboratory on Mars with devices that will find out for us as much as is possible about life on the planet. We will be in a position to examine the chemistry, metabolism, and reproduction of life if it exists there.

Intelligent Life

According to our calculations of the distribution of life in the universe, it is reasonable to assume that intelligent life must have evolved in a large number of sites. An estimate of the distribution of intelligent life in the universe, made by Carl Sagan, puts the figure at a million in our own galaxy. The distance between these civilizations may be as large as 1,000 light years. The separation between civilizations seems to be almost infinite by human standards. "There is one race of men; one race of gods; both have breath of life from a single mother. But sundered power holds us divided, so that one is nothing, while for the other the brazen sky is established their sure citadel forever," wrote Pindar in the sixth Nemean Ode.

Among the methods available for interstellar communication, nuclear particle radiation and electromagnetic radiation present themselves as possible methods. Nuclear particle radiation can carry information at the speed of light. While known useful nuclear particles possess far more energy than photons, their information content is very similar to that of electromagnetic radiation. Electromagnetic radiation may travel at the velocity of light with little interference to distances of 1,000 light years or more.

It is interesting to note that at the beginning of this century Madame Guzman of Paris left 100,000 francs to the French Academy of Sciences, as a prize to the first person who would communicate with another world, with the exception of the planet Mars, for Mars was thought to be within easy reach.

If electromagnetic communication is chosen as the best method of solving the problem, the next question centers around the best wave length at which to transmit a message. The first theoretical discussion of this was made in 1959 by Cocconi and Morrison who suggested that the optimum frequency for transmission would be that of the hydrogen line at 21 centimeters. The sub-harmonics and harmonics of the hydrogen line frequency have also been suggested as possible candidates. One search for intelligent signals has already been made on the hydrogen line frequency. The hydrogen line at 21 centimeters has been considered to be the one that intelligent beings somewhere in the universe might use. This is presumably because frequencies of lower wave length will be jammed by natural radio noise. According to Frank Drake, who directed project Ozma, this monumental search for intelligent beings in the universe may be compared to meeting a friend in New York City without making arrangements in advance about a meeting place. One does not just wander the streets looking everywhere. Instead, the most likely places to look are the places that are already familiar - Grand Central Station, for instance, or Times Square. There are similar places in every city with which most people are acquainted. This is what the radio astronomer is in search of - a grand central station of the galaxy - some special frequency about which everyone in the Milky Way would know. This indeed is the emanation of the hydrogen line.

The best place to seek for intelligent signals with our present state of knowledge seems to be to concentrate on the nearest stars. The two nearest for consideration are Tau Ceti in the constellation Cetus and the star, Epsilon Eridani in the constellation of Eridanus. Both of these are about 10 light years away.

In the search conducted at the Green Bank Observatory, each morning at 3 a.m. the telescope was pointed to Tau Ceti. When Tau Ceti set beyond the mountains, the telescope was swung to Epsilon Eridani and the search carried on. A signal was picked up twice; the same signal each time. The discovery was exciting, but moving the antenna showed that these were actually signals from the earth and not from space. At the end of two months endeavor no evidence of signals from space could be found on the records. These were the first steps of the endeavor at the National Astronomical Observatory in the project Ozma, named after the Princess Oz, who lived in the mythical land of Oz. It is clear that one should not be disappointed or discouraged because the first attempts of project Ozma to find another civilization have failed. It will take many long years with larger radio-telescopes and more sensitive receivers to have a good chance of success.

Sagan, in a theoretical discussion, has suggested that a civilization much more advanced than ours might have evolved methods of interstellar space flight under relativistic velocities. If relativistic velocities can be achieved, time dilation will permit long journeys within one human lifetime. Immense journeys that would normally require hundreds of millions of years would be performed within a lifetime of a human group. If these conditions were realized, and if we consider the distribution of advanced technology, it is possible that physical contact between such civilizations could take place almost every 10,000 years.

In his discussion, Sagan recalls a recent Russian publication which has called attention to several biblical incidents, considered to reflect possible contact with the extraterrestrial civilizations. The incidents narrated in the apocryphal book, "The Slavonic Enoch," are considered to be an account of the visitation of earth by extraterrestrial cosmonauts. Other legends are alluded to in this particular context; for example, the Babylonian account of the origin of the Sumerian civilization by the Apkallu, considered to be representatives of an advanced non-human and possible extraterrestrial society.

The Experimental Approach

The considerations so far in our search for extraterrestrial life have centered round life detection instruments and possible radio contact with other civilizations. We have, however, a down-to-earth approach to the problem. Laboratory experiments on earth can reveal which materials and conditions available in the universe might give rise to chemical components and structural attributes of life as we know it. As we noted earlier, the retracing of the pattern by which life appeared on earth would give strong support to the theory of its existence elsewhere in the universe. This is the study of chemical evolution.

The two main factors which provide the rational basis for the experimental approach to the problem of the origin of life are the triumph of the Darwinian theory of evolution and recent advances in molecular biology. According to Darwin, the higher forms of life evolved from the lower over a very extended period in the life of this planet. This idea, which caused so much dissension among the humanists of the last century, is today the cornerstone of modern biology. If this idea of biological evolution is carried to a logical conclusion, we must postulate another form of evolution before biological evolution, namely, chemical evolution. Recent studies in molecular biology and biochemistry have highlighted the remarkable fact that the two basic molecules in living organisms, nucleic acid and protein, have a remarkable kinship throughout the earth's biosphere. An inescapable conclusion is that all life must have a common chemical ancestry.

Over the years, several speculations had been made in this field, but the ideas that contributed most to a scientific awareness of the problem were those of Oparin. In clear and scientifically defensible terms he wrote in 1924 in a preliminary booklet published in Russian that there appeared to be no fundamental difference between a living organism and brute matter. The first English edition of his book was published in 1936 under the title of "The Origin of Life."

Several experimenters have put some of the theories concerning the origin of life to laboratory tests. One of the earliest was Calvin who, in 1951, used the Berkeley cyclotron to irradiate a mixture of carbon dioxide and water and produce small amounts of organic compounds such as formic acid and succinic acid. In the classic experiment performed by Miller in 1953 an electric discharge through a mixture of methane, ammonia, and water produced several amino acids. Since then, some of the constituents of the protein and the nucleic acid molecule have been synthesized under conditions which may be termed abiological. The raw material for such experiments has been methane, ammonia, and water. The sources of energy were ultraviolet light from the sun, electric discharges, ionizing radiation, heat, and, in some instances, the shock wave produced by simulated meteorite impact.

In our own laboratory we have adopted a simple working hypothesis that molecules which are of biological significance today were important at the time of the origin of life. We have, therefore, concentrated our search on the constituents of the nucleic acid molecule and the protein molecule. The analyses of the end-products of our experiments have often very surprisingly yielded these very same compounds. Starting with rudimentary molecules, we have synthesized adenine and guanine and the sugars, ribose and deoxyribose. The same sources of energy which were responsible for the synthesis of these primary molecules have also given us the nucleoside and the nucleoside phosphates, including the energy sources of all living substances, adenosine triphosphate. The results from our laboratory thus show that, under simulated primitive earth conditions, molecules of biological significance can be synthesized. They lend support to the hypothesis of chemical evolution since (1) the starting materials are the simple constituents of the primordial atmosphere, (2) the sources of energy are those that were most likely to have existed under primitive earth conditions, (3) the concentrations of material used are extremely small, and (4) most of the synthesis have been accomplished in an aqueous medium.

Recent studies in quantum biochemistry have thrown some light on very significant aspects of chemical evolution. Many of the molecules which are essential to living substances exhibit the phenomenon of electronic delocalization. These compounds have a great deal of stability and can be best adapted for biological purposes. It is not surprising to find that some of these molecules are most readily synthesized in simulation experiments.

There is no reason to doubt that we shall rediscover, one by one, the physical and chemical conditions which once determined and directed the course of chemical evolution. We may even reproduce the intermediate steps in the laboratory. Looking back upon the biochemical understanding gained during the span of one human generation, we have the right to be quite optimistic. In contrast to unconscious nature which had to spend billions of years, conscious nature has a purpose and knows the outcome.

In "The Phenomenon of Man," Pere Teilhard de Chardin, priest, philosopher and scientist, has attempted to give us a comprehensive picture of the evolving universe. To him, mankind in its totality is a phenomenon which could be described and analyzed like any other phenomenon. Though for certain limited purposes it may be useful to think of phenomena as isolated statically in time, they are in point of fact never static: they are always processes or parts of a process.

He speaks of complexification as an all pervading tendency, involving the universe in all its parts in an "enroulement organique sur soi-meme." The noosphere is a new layer or membrane on the earth's surface, superimposed on the living layer or the biosphere which, in turn, has evolved from the lifeless layer of inorganic material or the lithosphere. The presence of potential mind must be inferred in all material systems by backward extrapolation from the human phase to the biological, and from the biological to the inorganic.

Conclusion

Before the dawn of the twenty-first century, manned exploration of the solar system may tell us whether we are alone in our universe. Radio telescopes scanning the distant galaxies for intelligible messages may reveal the presence of our more remote neighbours. Laboratory experiments will endeavor to retrace the path of chemical evolution and may provide evidence for the existence of extraterrestrial life.

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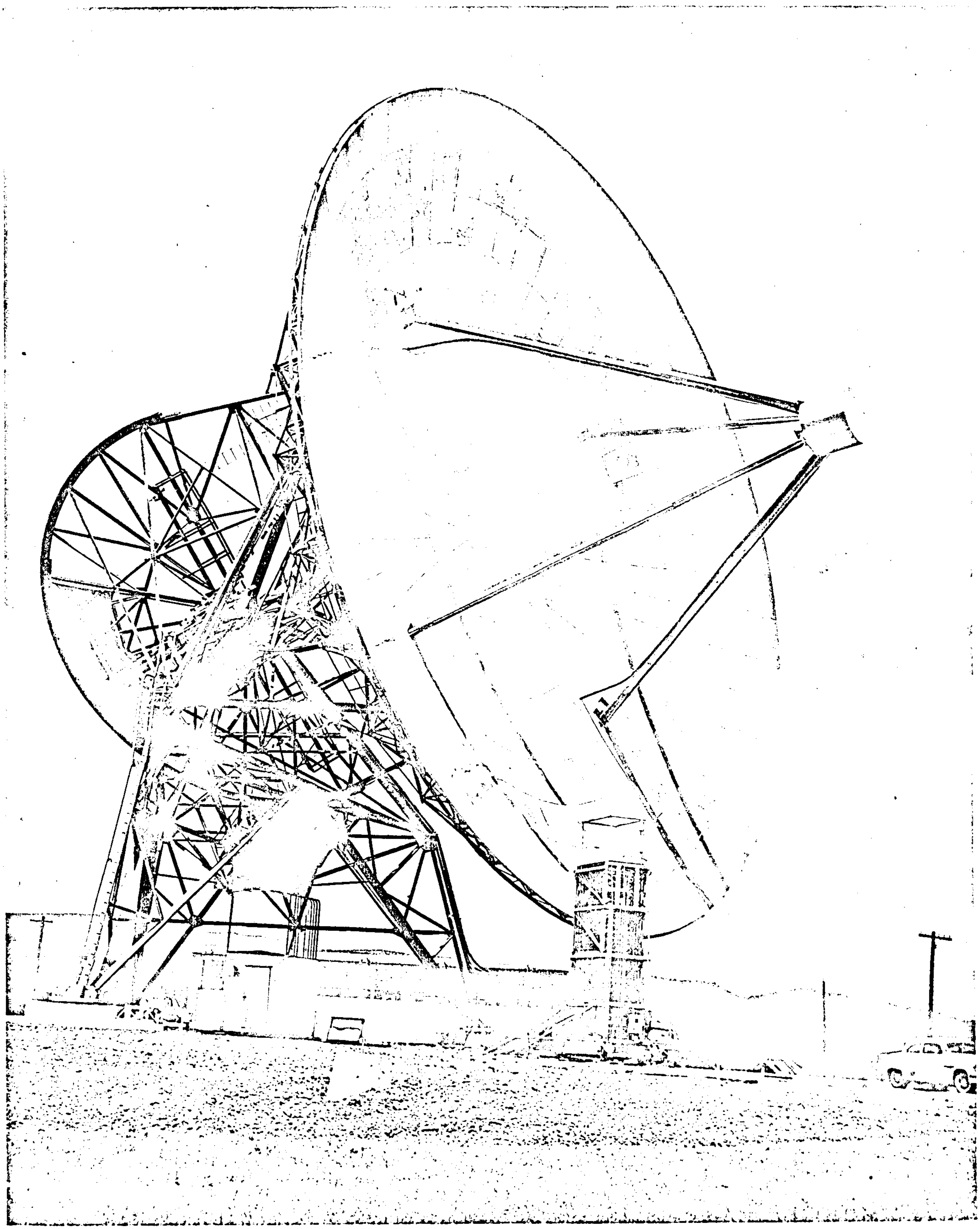

The Howard E. Tatel telescope used by Frank Drake
in his search for intelligent signals from space.

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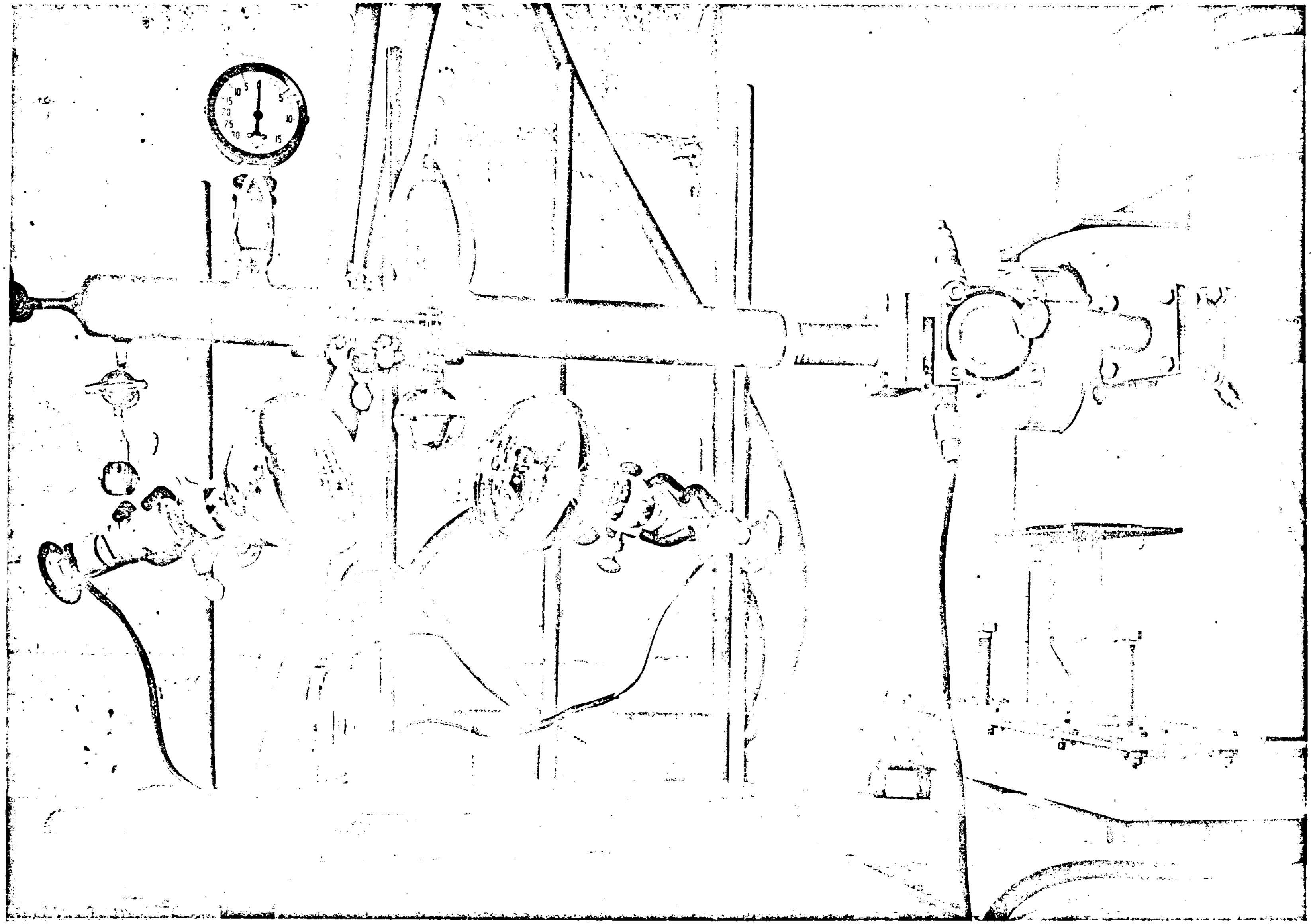

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